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Predicting a global insect apocalypse

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Abstract

1. The last three years have seen a global outbreak of media headlines predicting a global insect apocalypse and a subsequent collapse of natural ecosystems, a so-called “ecological armageddon” resulting in the demise of human civilization as we know it. Despite the worrying implications of these papers, all studies on global insect extinction to date clearly reflect the Prestonian shortfall, the general lack of knowledge on the abundance of species and their trends in space and time.

2. Data currently available concerning global insect abundance trends invariably suffer from phylogenetic, functional, habitat, spatial and temporal bias. Here we suggest that to follow the real global changes in insect (and all other taxa) communities, biases or shortcomings in data collection must be avoided.
3. An optimized scheme would maximize phylogenetic, functional, habitat, spatial and temporal coverage with minimum investment. Standardized sampling would provide primary data, on a first step in the form of abundance and biomass. Individuals would then be identified to species level whenever possible, with a morphospecies approach or genetics serving as intermediate steps, complementing or even final steps for non-described species.
4. If standardized abundance and ecological data can be readily made available, biodiversity trends can be tracked in real time and allow us to predict and prevent an impending global insect apocalypse.

The last three years have seen a global outbreak of media headlines predicting a global insect apocalypse and a subsequent collapse of natural ecosystems, a so-called "ecological armageddon" resulting in the demise of human civilization as we know it. The stimulus for this has been the publication of a number of papers highlighting dramatic declines in insect abundance or biomass (Halmann *et al*., 2017, Sánchez-Bayo & Wyckhuys, 2019). Despite the worrying implications of these papers, all studies on global insect extinction to date clearly reflect not only the Prestonian shortfall, the general lack of knowledge on the abundance of species and their trends in space and time (Cardoso *et al*., 2011) but also the Linnaean shortfall, our ignorance of exactly how many species there are (Brown & Lomolino, 1998).. This is in part due to the extreme species richness of insects, conservative estimates suggest at least five million extant species (Hamilton *et al*., 2013), their ubiquity across space and time, and the consequent dearth of information concerning their evolutionary history and ways-of-life. As the dominant form of living organisms, the state of insect populations can be closely equated with that of biodiversity and the fate of humanity.

Data currently available concerning global insect abundance trends invariably suffer from phylogenetic, functional, habitat, spatial and temporal bias. They often focus on the better-known taxa, representing a relatively small proportion of the tree of life (Leather, 2018), with consequent phylogenetic and functional bias. Pollinators for example, mainly represented by bees (Apoidea), have been the target of numerous funding initiatives which have generated an exponential increase in the number of studies over the last decade and probably have far more data than any other insect group. Forests and agricultural areas, Europe and the Nearctic, are often overrepresented (Sánchez-Bayo & Wyckhuys, 2019). Often conclusions are based on short-term data and/or data with two or very few points that do not allow us to disentangle true decline from natural fluctuations.

After collection, the data extracted from the samples are often not uniform. Many of the recently found trends in insect decline are based on abundance or biomass, the simplest forms of quantifying some variable of interest with direct implications in ecosystem function. Yet, species identification, or when not possible due to the Linnaean shortfall, as is common for the richest regions in the planet, morphospecies or genetic species delimitation, is needed to allow understanding the many facets of community change. The loss of individuals and biomass of rare or unique species might be masked by the increase in common or invasive taxa. Finally, sampling and the data derived from it are often not standardized, making it difficult to confirm the suspected changes.

Here we suggest that to follow the real global changes in insect (and all other taxa) communities, biases or shortcomings in data collection must be avoided (Fig. 1). It is impossible with the resources available to us to identify and follow the trends of every single species of insect across even moderately sized areas. As we are probably arriving late to the game, it is important that existing data, from multiple sources such as museum collections and citizen science projects, must be unearthed and linked to schemes currently being mobilized (Cardoso *et al*., 2011). It is also blindingly obvious, that existing studies should continue to be fully supported and new studies funded (Leather, 2018). After appropriate measures to avoid biases (e.g., careful selection of comparable data, spatial/environmental thinning) have been taken, these can used as a first approximation to the problem. A more robust monitoring system is, however, badly needed.

Standardizing and optimizing the sampling methods and target taxa to cover the maximum phylogenetic and functional diversity is possible (Cardoso *et al*., 2016). At national levels, a number of schemes already exist. For example, the Environmental Change Network (http://www.ecn.ac.uk/) collects biotic and abiotic data, including many insect groups, from 57 different sites across the UK using identical protocols (Rennie, 2016). Setting up a global and long-term monitoring scheme covering all major habitat types will not require mega-funding, but only if the distribution of available resources is optimized, maximizing the return for the investment. As a first step, measuring abundance and biomass should be prioritized. They are easily quantifiable and provide valuable data on their own, and, importantly, their collection is relatively inexpensive and easy to standardize. On their own however, these data are of limited value. Extra value can be gained by species level identification, so that, for example, changes at the community level can be tracked properly. This will, however, require more expertise and training, and inevitably, more expense. For megadiverse regions or taxa, species are often undescribed, hence a morphospecies approach might be needed, particularly useful if framed within a cyberdiversity platform that allows comparability between projects and teams (Miller *et al.*, 2014). Alternatively, the definition of putative species based on genetic markers, namely barcodes, might allow such comparability for species still without a name or help in the identification of described species. The resulting data can then be fed to a central repository that allows real-time tracking of changes as they happen, even if data input is not simultaneous across regions.

Several schemes already exist from which one could learn from experience of what works and what does not, thus avoiding past pitfalls. The Living Planet Index (Loh *et al*., 2005) successfully builds on multiple vertebrate monitoring schemes at a global level. Multiple Long-Term Ecological Research projects track different facets of ecosystems in different ways (Magurran *et al*., 2010). In fact, the LTER network, if expanded to a global scale, could be the natural framework to make our proposal feasible, possibly through a targeted step change in funding (Thomas *et al*., 2019).

A globally coordinated scheme and database such as the one envisaged, would facilitate multiple joint scientific project proposals and publications targeting different questions, and would encourage experts from across the world to participate in a common endeavor (Hudson *et al*., 2017, Dornelas *et al*., 2018). Legacy species distribution data are currently centralized using global standards within the Global Biodiversity Information Facility, and are freely available for analysis. If standardized ecological data can be added to this or similarly valuable resources, biodiversity trends can be tracked in real time and allow us to predict and prevent an impeding global insect apocalypse.

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Bibliography

Brown, J.H. & Lomolino, M.V. (1998) *Biogeography*, 2nd edn. Sinauer Press, Sunderland, Massachusetts.

Cardoso, P., Erwin, T.L., Borges, P.A.V. & New, T.R. (2011) The seven impediments in invertebrate conservation and how to overcome them. *Biological Conservation*, **144**, 2647-2655. doi: 10.1016/j.biocon.2011.07.024.

Cardoso, P., Carvalho, J.C., Crespo, L.C. & Arnedo, M.A. (2016) Optimal inventorying and monitoring of taxon, phylogenetic and functional diversity. *bioRxiv*. doi: 10.1101/060400.

Dornelas, M., Antao, L.H., Moyes, F., Bates, A.E., Magurran, A.E., Adam, D., ... Zettler, M.L. (2018) BioTIME: A database of biodiversity time series for the Anthropocene. *Global Ecology and Biogeography*, **27**, 760-786. doi: 10.1111/geb.12729.

Hallmann, C.A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., … de Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS One*, **12**, e0185809. doi: 10.1371/journal.pone.0185809.

Hamilton, A.J., Novotny, V., Waters, E.K., Basset, Y., Benke, K.K., Grimbacher, P.S. … Stork, N.E. (2013) Estimating global arthropod species richness; refining probalistic models using probability bound analysis. *Oecologia*, **171**, 357-365. doi: 10.1007/s00442-012-2434-5.

Hudson, L.N., Newbold, T., Contu, S., Hill, S.L.L., Lysenko, I., De Palma, A., … Purvis, A. (2017) The database of the PREDICTS (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems) project. *Ecology and Evolution*, **7**, 145-188. doi: 10.1002/ece3.2579.

Leather, S.R. (2018) "Ecological Armageddon" - more evidence for the drastic decline in insect numbers. *Annals of Applied Biology*, **172**, 1-3. doi: 10.1111/aab.12410.

Loh, J., Green, R.E., Ricketts, T., Lamoreux, J., Jenkins, M., Kapos, V. & Randers, J. (2005) The Living Planet Index: using species population time series to track trends in biodiversity. *Philosophical Transactions of the Royal Society of London B*, **360**, 289-295. doi: 10.1098/rstb.2004.1584.

Magurran, A.E., Baillie, S.R., Buckland, S.T., Dick, J.M., Elston, D.A., Scott, M., … Watt, A.D. (2010) Long-term datasets in biodiversity research and monitoring: assessing change in ecological communities through time. *Trends in Ecology and Evolution*, **25**, 574-582. doi: 10.1016/j.tree.2010.06.016.

Miller, J.A., Miller, J.H., Pham, D. & Beentjes, K.K. (2014) Cyberdiversity: improving the informatic value of diverse tropical arthropod inventories. *PLoS One*, **9**, e115750. doi: 10.1371/journal.pone.0115750.

Rennie, S.C. (2016) Providing information on environmental change: Data management. Discovery and access in the UK Environmental Change Network data. *Ecological Indicators*, **68**, 13-20.

Sánchez-Bayo, F. & Wyckhuys, K.A.G. (2019) Worldwide decline of the entomofauna: a review of its drivers. *Biological Conservation*, **232**, 8-27. doi: 10.1016/j.biocon.2019.01.020.

Thomas, C.D., Jones, T.H. & Hartley, S.E. (2019) "Insectageddon": a call for more robust data and rigorous analyses. *Global Change Biology, accepted article.* doi: 10.1111/gcb.14608.

Fig 1 – Proposal for a monitoring system. An optimized scheme would maximize phylogenetic, functional, habitat, spatial and temporal coverage with minimum investment. Standardized sampling would provide primary data, on a first step in the form of abundance and biomass. Individuals would then be identified to species level whenever possible, with a morphospecies approach or genetics serving as intermediate steps, complementing or even final steps for non-described species. All these data would feed into a common database, allowing an alert system in real-time.